TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 82.

ONLY COPY

NOTES ON THE CONSTRUCTION AND TESTING OF MODEL AIRPLANES.

By

Walter S. Diehl,
Bureau of Aeronautics, U.S.N.

January, 1922.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL NOTE NO. 82.

NOTES ON THE CONSTRUCTION AND TESTING OF MODEL AIRPLANES

by

Walter S. Diehl.

Introduction.

In most wind tunnels the construction and test of a model aerofoil or fuselage is standardized, but in the endeavor to secure a non-turbulent air flow and great refinement in force measurements, the general requirements for construction and tests of model airplanes or seaplanes have been neglected. The average airplane model is constructed to scale from general assembly plans with detail depending on the skill of the model maker. As one result the cost of a model is very high. As another result the test data is frequently unreliable.

The following notes are intended to supplement Mr. F. H. Norton's paper on "The Construction of Models for Tests in Wind Tunnels" (National Advisory Committee for Aeronautics' Report No. 74). It will be shown that the construction of an airplane model can and should be simplified in order to obtain the most reliable test data.

General Requirements in Model Construction.

The general purpose of the usual wind tunnel tests on a model airplane is to obtain the aerodynamic characteristics, the static balance, and the efficiency of the controls for the particular combination of wings, tail surfaces, fuselage and landing gear employed in the design. These parts must be exact scale reproductions. Any appreciable variation from scale reproduction must be in the remaining parts of the model, i.e., struts, wires, fittings, control horns, radiators, engines and the various attachments found exposed to the wind in special airplanes.

Obviously the wings, tail surfaces, fuselage and landing gear must be rigidly held in the proper relation, one to another, preferably with means for minor adjustments. These requirements are easily met in models of internally-braced monoplanes, but they usually cause trouble in models of multiplanes, particularly when an attempt is made to provide an <u>exact scale reproduction</u> of the interplane bracing in accordance with the popular conception of model requirements. Although model struts and fittings are very minute and difficult to make, their use would be justified if a model so constructed was rigid and capable of minor adjustments and if it in test fairly represented the full scale airplane.

Interplane Bracing.

Figure 1 represents an average attempt to secure an exact scale reproduction in a wind tunnel model. The result is a flimsy affair which is not only difficult to line up, but also difficult to keep adjusted. The values of drag obtained from tests are from 30% to 50% higher than the values obtained from calculations, which allow for a normal scale effect. This great difference in drag is due to the abnormal scale effect for struts and wires at low values of VL. Figure 2 is included to illustrate the magnitude of this scale effect. The average full scale strut, say 2" thick at a velocity of 100 f.p.s., has the following characteristics:

$$VL = 16.7$$

$$D_c = 0.043$$

For a 1/24 scale model tested at 50 f.p.s., the characteristics will be

$$VL = \frac{16.7}{24 \times 2} = 0.35$$

$$D_c = 0.180$$

Consequently, the resistance of a model strut is about four times as great as its proportional full scale value.

The scale effect on wires and cables is about one-half of the scale effect on struts. The scale effect on fittings is unknown, but it is reasonable to assume that it is of the same order as that for the wires. It therefore appears useless to

employ an exact reproduction of the interplane bracing on models. This fact has been recognized in the construction of certain models, in which, according to the test reports, the omission of interplane wiring was supposed to allow for the scale effect on the struts. This assumption is hardly justified in general use although it may give a fair approximation in those cases having a certain degree of balance between the struts and wires. Even with this simplification there still remain the requirements of rigidity and minor adjustment which are always difficult to meet with the model streamline struts.

As the result of investigations made at the Washington Navy Yard wind tunnels and extending over a period of three years, it has been concluded that the best results are obtained by omitting all of the struts, wires, and fittings, as such, and holding the model together with the fewest possible number of small cylindrical brass struts consistent with rigidity and adjustment. These struts are usually fitted in symmetrical pairs without reference to the location of struts on the full scale airplane. It is found that three pairs are sufficient for the average biplane model. Adjustment is obtained by fitting the struts with R.H. and L.H. threads into corresponding bushings in the lower and upper wing. The diameter of the wire used depends upon the size of the model and varies from 0.030" to 0.100", the average being approximately 1/16".

Tests have shown that the lift of these wires is negligible and that their drag is substantially constant over the usual range of flying angles. A very close approximation to the true model scale drag of the airplane may therefore be obtained by correcting the observed model drag for the difference between the drag of the cylindrical struts and the scaled down value of the calculated drag for the full scale interplane bracing, i.e.

$$D' = D - D_W - D_C$$

where

D' is the corrected model drag,

D the observed model drag,

D_W the drag of the cylindrical struts used on the model, and D_C the calculated model equivalnet on the full scale interplane bracing drag, assuming that it varies as $(VL)^2$. Since this assumption is always made in converting the model test data to full scale values, the preceding operation is, in effect, the equivalent of a scale correction for the interplane bracing.

Corrections may also be made to pitching moments if desired. It is recommended that in each case the moment of $(D_C - D_W)$ about the c.g. be compared with the total moment in order to weigh the necessity of this correction. In most cases it may be neglected.

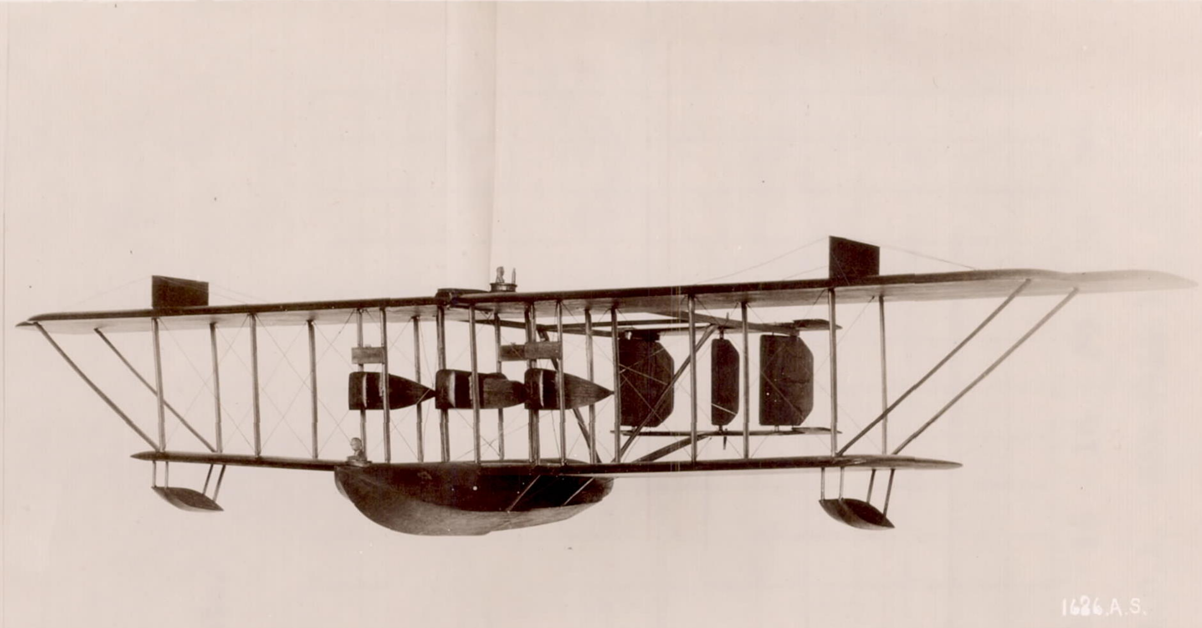


FIG. 1

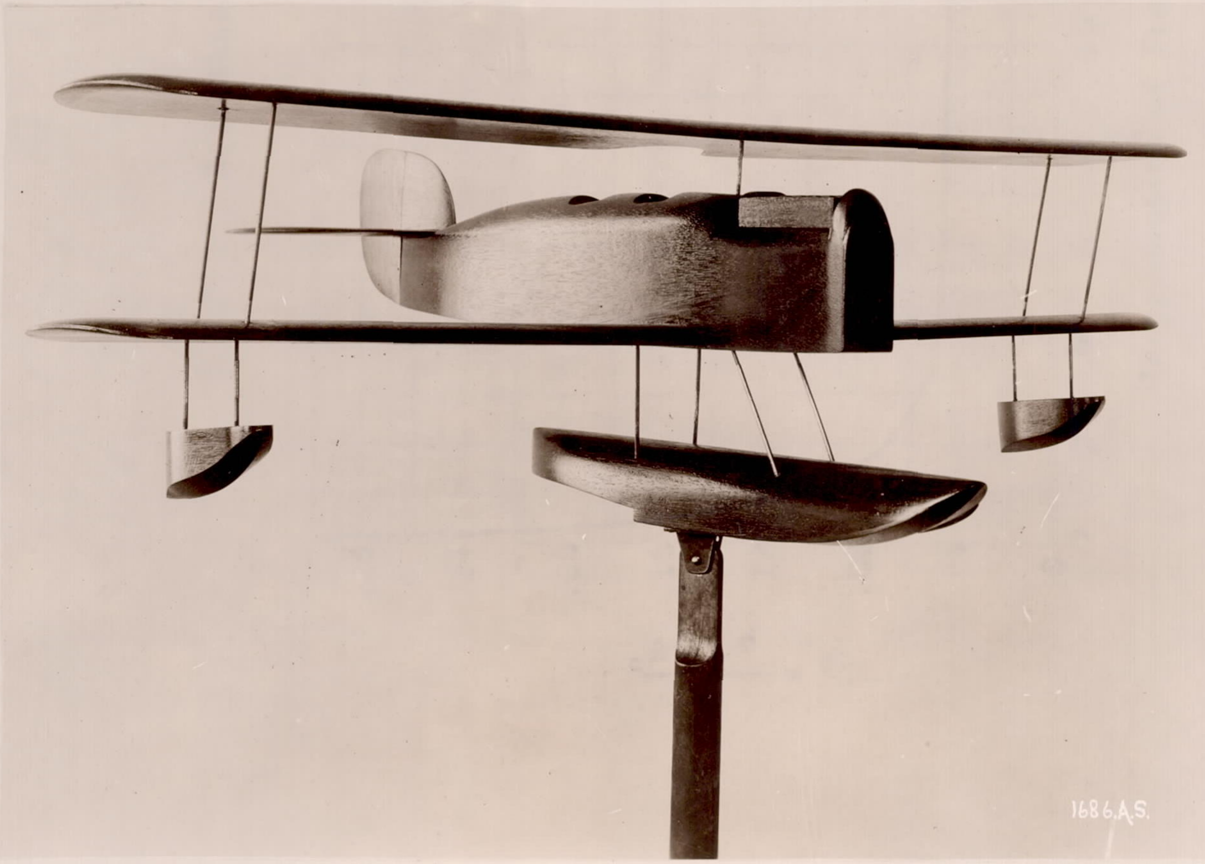


FIG. 3

Minor Detail.

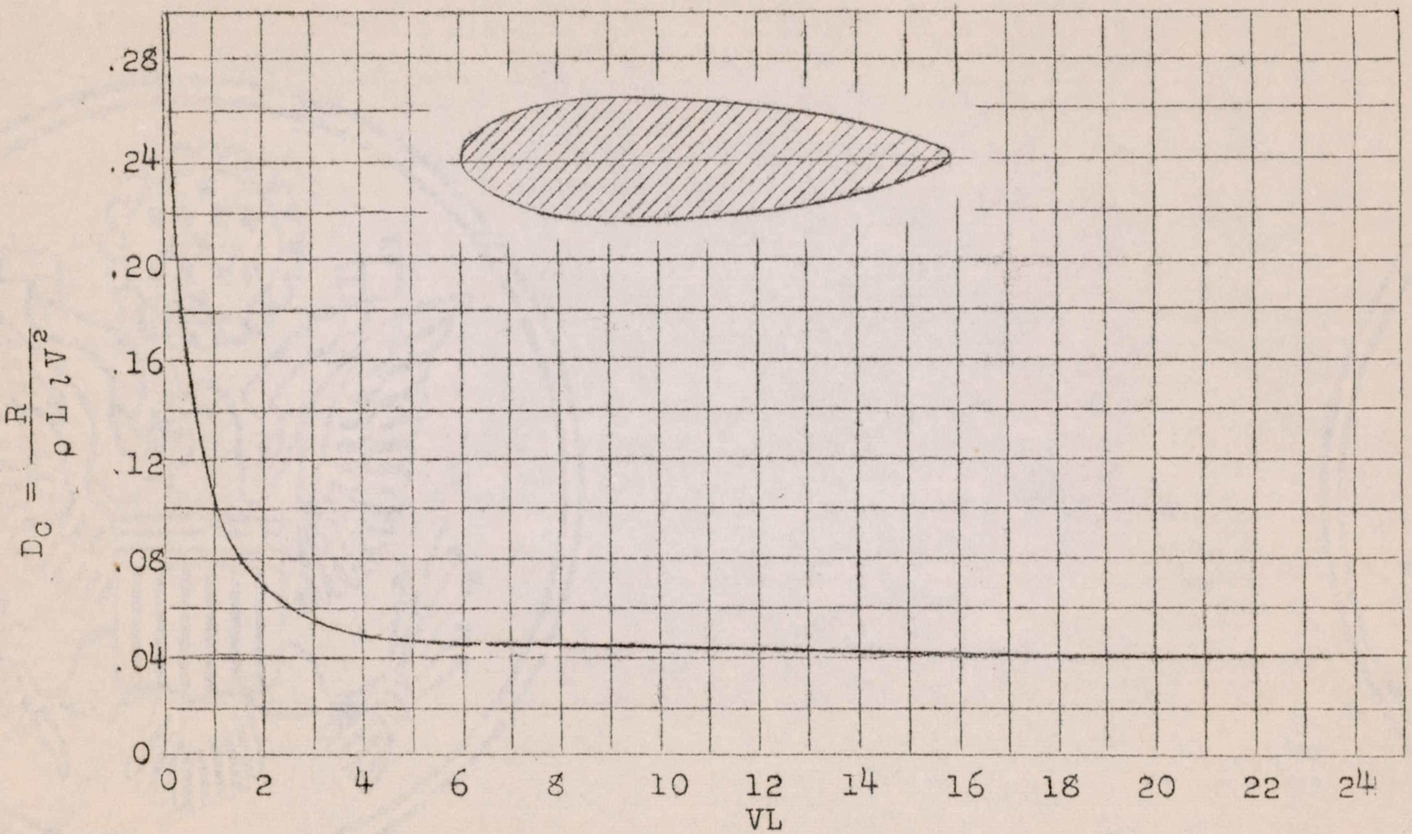
The construction of the model may be further simplified without affecting the accuracy of the test results. For instance the control cables, and in most cases the control horns, should be omitted and their resistance included in the correction D_c.

Radiators have approximately one-half of the resistance of a flat plate of equal frontal area. Free air radiators may therefore be approximated by a flat plate whose linear dimensions are 70% of those of the radiator. In case there are objects in the wake of the radiator it is desirable to use a piece of gauze which has a resistance coefficient equal to radiator core. Nose radiators should be made according to the method described in N.A.C.A. Report No. 74.

Very little detail should be used on engine cylinders, wind shields, wing skids, tail skids, shock absorbers, etc. These parts have very little effect on the total resistance and it has been found that the extra labor required to put in the detail is not justified.

Figure 3 represents the appearance of a model which embodies in its construction the foregoing simplifications. This model is rigid and easily adjusted; on test it gives satisfactory results. The cost of construction is reduced approximately 50% compared with an exact scale model.

Resistance of Struts.



(Reproduction of Fig.2 - Br.A.C.A. R&M #416.)

Fig. 2.